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Viable and convivial technologies: Considerations on Climate Engineering from a degrowth perspective

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ABSTRACT

Faced with the urgency of climate change, Climate Engineering has been framed as a fast and feasible technological solution. At the same time, however, critique against it is getting increasingly louder. This paper articulates a critical analysis of Climate Engineering technologies from a point of view situated within the degrowth discourse. In the first part two approaches discussed within the degrowth debate are presented: the concept of *viability* based on a biophysical perspective and the concept of *conviviality* based on a socio-cultural approach. In a second step formalized arguments from the point of view of applied ethics are articulated and applied to three Climate Engineering Technologies: Sulfate Aerosol Injection, Bio-energy with Carbon Capture and Storage, and Afforestation. In a third step, an extended version of the trade-off argument about mitigation versus Climate Engineering solution is discussed from a degrowth perspective: accordingly, within the current dominant growth paradigm, climate engineering technologies might lead to reduced mitigation efforts. The paper follows the argumentative turn in applied ethics and displays a formalization of arguments that can help clarify decision-making and identify the different dimensions at stake. The paper articulates arguments against the deployment of CE technologies and advances a new version of the trade-off-argument based on a degrowth perspective. From the point of view of a degrowth-based critique of technology, the only type of Climate Engineering Technology ethically acceptable would be afforestation under specific conditions.

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1. Introduction

The idea to manipulate the earth's climate system in order to combat climate change has begun to attract both scientists and the public. Given the inertia of the climate system as well as the missing commitment of the Industrial World to cut emissions, it seems increasingly less likely that current political efforts will be able to stabilize temperature-rise globally at 2 °C. Reaching this "2-degree-target", however, was the latest agreement at the twenty-first Conference of the Parties (COP21) in Paris in Winter 2015. The Conference of the Parties, which is held under the United Nations Framework Convention on Climate Change (UNFCCC), has published their results as the "Paris Agreement" (UNFCCC, 2015). The Paris Agreement goes even further and aims at "*holding the increase in the global average temperature to well below 2 °C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 °C*" (UNFCCC, 2015: 21).

However, as the UNFCCC Secretary recently has observed, none of the emission pledges (Intended National Determined Contributions, INDCs) of the parties fall within a 2-degree-pathway (UNFCCC, 2016). There is an anticipated emission overshoot that only slowly will come down in the second half of the century. To stabilize temperature by the end of the century, this overshoot would have to be balanced. From this point of view, since mitigation alone might not do the trick, R&D and future deployment of Climate Engineering technologies might turn out to be unavoidable. A pathway consistent with a 2-degree-warming most likely will depend on the deployment of Negative Emission Technologies (NETs), mainly Bio-energy with Carbon Capture and Storage (BECCS). The latest report of the Intergovernmental Panel on Climate Change (IPCC) has included scenarios that treat BECCS as an option to stabilize temperature. Most notably, 87% (101 out of 116) of the scenarios that reach 430–480 ppm CO_2-eq by 2100 – an amount that is consistent with a 2-degree-warming – assume the deployment of NETs (Fuss et al., 2014; Allwood et al., 2014; Schäfer

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et al., 2015). In this light, the advocacy of Climate Engineering (CE) grows louder – as does the critique.

This paper examines two critical perspectives on technology (*viability* and *conviviality*) situated within the degrowth discourse and applies them to Climate Engineering Technologies by employing the method of formalized arguments as it has been articulated by current research in the field of the ethics of CE. In particular, the paper follows what recently has been dubbed the "argumentative turn" in applied ethics as a methodological approach (Hansson and Hadorn, 2016). Based on the two criteria here presented, a formal argument reconstruction is displayed and applied to CE. When confronted with major uncertainties, argument analyses may help clarify decision-making and identify the different dimensions at stake. Arguments are presented as premise-conclusion-structures in natural language. In making implicit assumptions transparent and highlighting normative decision principles, argument analysis helps to understand the uncertainties and weigh the benefits and side-effects of a political decision (Betz, 2010a; also Betz, 2010b; 2012). Climate change and the contemplation of CE deployment surely is an instance of highly uncertain policy making, where argument reconstruction proves to be helpful.

In a first step, the concepts of *viability* and *conviviality* are presented and in a second step converted into formalized arguments. In the nuanced discussion of CE technologies that follows, the specific features of each technology are addressed in light of the degrowth critique. From the degrowth perspective here presented it results that an acceptable CE technology would have to prove to be both convivial and viable. Three common technologies en vogue in the Climate Engineering Debate, Sulfate Aerosol Injection (SAI), Bio-energy with Carbon Capture and Storage (BECCS) and Afforestation (AFF) are examined. In a third step, the paper discusses an extended version of the Trade-Off Argument about mitigation versus Climate Engineering solution from the point of view of the critique of growth as a business as usual path.

2. What is climate engineering?

Climate change confronts us with a new, unprecedented challenge regarding technology. The critique against the hegemony of non-transparent and uncontrollable technology is at odds with the view that climate change can only be solved by technical means, such as Climate Engineering. Despite critical voices, due to both political and physical inertia, the deployment of CE is rather likely. Many effects of carbon dioxide already present in the atmosphere cannot be reversed (Solomon et al., 2009) and in the last decades climate change has started affecting the planet in evident ways. Glaciers are losing substance, the oceans are warming up and sea level has risen between 1901 and 2010 at a rate that is larger than the mean rate during the last millennia (Allwood et al., 2014). At this point in time, it seems hard to avoid catastrophic climate impacts by mitigation alone. According to Gardiner, the problem of climate change, which is a human-made problem that has not been yet properly addressed, is vulnerable to *"moral corruption"* (Gardiner, 2010: 287). Climate Engineering supposedly offers a feasible solution.

Climate Engineering is defined as "*deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change*" (Royal Society, 2009: 1), aims at delaying or even offsetting climate change by technical means such as stabilizing the temperature or removing CO_2 from the atmosphere. According to those two basic features, one can distinguish two kinds of CE technologies: Solar Radiation Management and Carbon Dioxide Removal.

2.1. Solar Radiation Management

Solar Radiation Management (SRM) influences the energy balance of the earth by reflecting the incoming sunlight. One set of SRM schemes consists in cloud modification. Clouds can be artificially produced (*cloud seeding*) and their ability to reflect sunlight can be enhanced by changing their composition (*cloud whitening*). Given the already poorly understood mechanism behind cloud forming, this approach is still in its infancy. Placing reflecting particles in space (*sun shields*) can also be an example of SRM.

The observation of temperature declining after the Mount Pinatubo eruption brought about the idea of one specific type of SRM technology: *Sulfate Aerosol Injection (SAI)* (Crutzen, 2006). Small particles of sulfate in the upper atmosphere would reflect the incoming sunlight, thereby stabilizing the ambient air temperature at a certain degree. Currently, SAI is the most prominently discussed SRM-Technology for it is deemed to be cheap and effective (Barrett, 2008; Keith, 2013). SAI advocates consider it a 'Back-up-plan', a kind of insurance in case all other efforts to combat climate change should fail.

Several studies attest SAI's ability to stabilize the temperature (e.g. Lenton and Vaughan, 2009; Keller et al., 2014; Schäfer et al., 2015; McNutt et al., 2015). However, SAI poses many technical, ethical and political problems. Temperature, in fact, is by no means the only problem related to climate change. Since SAI does not change the CO_2 concentration in the atmosphere, it cannot address problems caused by it, such as the acidification of the oceans (Robock, 2008). Moreover, SAI will most likely affect precipitation patterns over the world in unpredictable ways, thus possibly leading to droughts or floods in countries already affected by climate change. It is also not clear who will regulate the development, let alone the deployment of this technology. Last but not least, precisely because of its ability to serve as a 'back-up-plan', the danger of lessening mitigation efforts in light of Climate Engineering could be a real problem (Royal Society, 2009).

2.2. Carbon Dioxide Removal

There are alternative CE technologies that directly aim at reducing the CO_2 amount in the atmosphere. Those technologies form the spectrum of Carbon Dioxide Removal (CDR). The removal of CO_2 from the atmosphere may happen through mechanical or chemical carbon capture, e.g. via '*artificial trees*' or *biochar*, or by enhancing natural CO_2-sinks, such as *ocean fertilization* or *afforestation*.

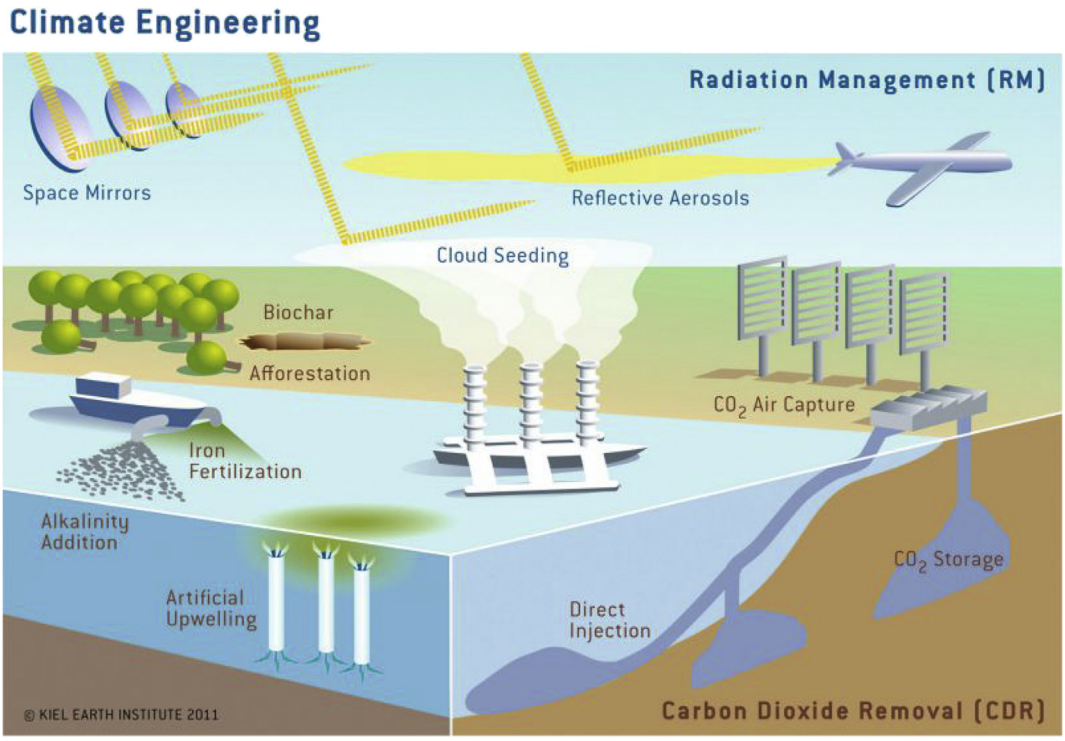
Trees and forests are a natural CO_2 sink. Afforestation measures envision to grow trees in areas that are not or no longer viable for agriculture. Afforestation might be integrated in a land-use management approach, together with Reforestation and avoided Deforestation. While there might be co-benefits to nature conservation, land-use conflicts could arise (Royal Society, 2009).

Recently, one specific technology has attract attention: Bio-Energy with Carbon Capture and Storage (BECCS). It combines the idea of enhancing natural sinks with the technical storage of CO_2. While biomass is growing, it sequesters CO_2 from the atmosphere. When being burned for energy use, the released CO_2 can be captured at source and be stored. This way BECCS would be in theory carbon negative. BECCS figures prominently in the latest IPCC report (Allwood et al., 2014) and is covered extensively in the media (see Feldpausch-Parker et al., 2015). Even though BECCS is a hopeful new technology, it is also associated with many uncertainties and technical as well as ethical problems. It competes with agriculture for land-use, and might therefore lead to a rise in food prices (Muratori et al., 2016; Lotze-Campen et al., 2014). Moreover, the search for "safe" storing sites would raise issues of

both procedural and distributional justice.

2.3. Overview of climate engineering technologies

An overview of different CE technologies is presented in the image below. As Betz and others have recently suggested (Betz and Cacean, 2012), any argument in support of or against CE can only be meaningful if it relates to a specific technology. This paper focuses in particular on three specific CE technologies and evaluates the moral arguments with respect to them.



Overview on the most prominent CE technologies - Image courtesy of Rita Erven, Kiel Earth Institute

Our paper focuses on SAI, Afforestation and BECCS, respectively, as three examples of CE technologies. While the CE landscape consists of a variety of different approaches, there are good reasons for this selection. Amongst SRM technology, SAI has gained the greatest attention. It was one of the first climate engineering technologies to be openly advocated (Crutzen, 2006) and has quite a large and robust scientific research base (Schäfer et al., 2015; McNutt et al., 2015; Rickels et al., 2011). Afforestation ranges on the opposite side of the CE spectrum and will be discussed as a contrasting example for SAI.

With respect to CDR technologies, BECCS seems to be the most promising. It might positively contribute to a change in energy policy while providing a negative emission technology. On the other hand, the difficulties related to BECCS are similar to other carbon storage technologies. Therefore, BECCS will be discussed by way of example for CDR technologies.

3. Requirements for sustainable technologies from a degrowth perspective

3.1. What is degrowth?

While it is hard to speak in general of 'one' degrowth movement, it is nevertheless possible to identify some common lines and theoretical inspirations for what can be considered as a slogan for a social movement (Petridis et al., 2015). In a strict sense, degrowth refers to a transition to a quantitatively smaller and qualitatively different economy that implies a gradual and equitable downscaling of production and consumption (ibidem). In a wider sense, degrowth articulates a structural critique of the growth-dependency of modern, capitalistic societies and envisions a radical social-ecological transformation of their basic institutions along a democratic and solidarity-based path (Muraca, 2013).

The degrowth movement, which has developed through different phases and regions since the late 1990s,[1] has rejuvenated the controversial debate around the *limits to growth* from the 1970s in a novel and original way. It has managed to interlink ecological economics research with a structural analysis and a socio-cultural critique of the functioning of contemporary growth-societies, thus ultimately re-politicizing the sustainability debate (Petridis et al., 2015). While some of the inspirations of the degrowth movement, when taken individually, are not new, its original potential lays in the cross-fertilization among the different sources and critical perspectives.

In the degrowth discourse, the critique of economic growth does not only address the fixation on measures like GDP (Gross Domestic Product) or the increase of the matter and energy flows in an economy, but also analyzes growth both in terms of a structure for societal stabilization and as a mental infrastructure (Welzer, 2011) that colonizes the life-world. While it can be acknowledged that economic growth has played a structural role in stabilizing modern, industrialized societies of the Global North, by guaranteeing employment, social mobility, tax revenue, and social pacification, it is also true that this stabilization was rooted in an ongoing expansion and intensification of productive activity. Economic growth requires the constant occupation of new territories in a

[1] For a detailed presentation of the history of the degrowth movement in its different variants see i.a. Muraca and Schmelzer 2017.

literal (land grabbing, shifting exploitation frontier and new extractivism) and metaphorical sense (acceleration of the pace of life, commodification of ecosystem services, deregulation of labor and money), and in the long run leads to crisis and destabilization. We are currently faced with a double economic-ecological crisis, in which measures to enhance economic growth inevitably increase the pressure on the ecological systems and in the long run compromise not only economic development, but also erode the basis of democracy (Dörre et al., 2015). While envisioning a return to the golden age of growth as the overall panacea, current business-as-usual politics do not only exacerbate the pressure on the environment, but also jeopardize democratic stability and social cohesion, as degrowth scholars have shown (Petridis et al., 2015). Green Growth strategies are no exception to this picture (Brand, 2012). Even if the impacts of Greenhouse Gas emission (GHG) were diminished by CE measures put in place to support a business-as-usual growth path, the willingness to take risks for accessing fossil sources (fracking, deep-water drilling) and to push exploitation beyond collectively negotiated boundaries (in natural reserves, fisheries, etc.) would still dramatically increase (Petridis et al., 2015). According to degrowth scholars, maintaining a growth path at any cost will lead to an even more dramatic destabilization of industrialized societies. What is needed instead is a radical social and ecological transformation of basic societal institutions that might help transitioning towards a society independent from the growth addiction (Muraca, 2013). Any short-term measure to protect the business-as-usual growth path is going to increase the pressure on the biophysical environment and exacerbate social conflicts worldwide.

In the following sections two different approaches on technology are examined from a degrowth perspective: a biophysical and a sociopolitical/cultural approach.

3.2. The exosomatic development of humans and the distinction between feasible and viable technologies

Georgescu-Roegen, without doubt one of the fundamental inspiration of the degrowth movement, considers technology as an essential element of the cultural development of human beings. Other than most non-human living beings, humans evolve and develop not only biologically by the transformation of their bodies over a long time (*endosomatically*), but also outside of their physical bodies (*exosomatically*) by employing external instruments and tools that transform their environment culturally (Georgescu-Roegen, 1971). Accordingly, economic activity is the specifically human extension of biological evolution that aims at securing not only bare surviving, but the enjoyment of life (ibidem). Technology is its manifest face.

Rather than being mechanical and reversible phenomena – as neoclassical economics treats them – economic processes rely like biological processes on the qualitative difference between available and non-available energy and are as such creative, metabolic, and qualitatively transformative. In physical terms, living beings are 'open systems' that keep their internal entropy low by incorporating the low entropy of the environment while releasing in turn high entropy to the environment itself. Economic processes as well feed on the low entropy of their environment and are irreversible: they are the outcome of cumulative, qualitative transformations that occur along the line of *Time* (with capital 'T') as a continuum that, just like historical time, cannot be reversed (Georgescu-Roegen, 1971, 125ff). Although such a concept of *Time* is hard to model in analytic-mathematical terms (mostly *time* is reduced to the measurement of an interval), it corresponds immediately to the unidirectionality and vectoriality of our own experience as living beings and as humans. In other words we 'know' very well about the irreversibility of living processes in our own experience even if neoclassical economics does not have instruments to represent it analytically and therefore ignores it.

Rather than marking some absolute planetary limits, the entropy law for Georgescu-Roegen allows us to frame the unidirectionality of *Time* and the irreversibility of creative, qualitative, and cumulative (since path-dependent) processes. From this point of view, planetary limits refer to the *rate* of use of resources and to the temporal conditions (and limitations) for the regeneration of organic, living processes (Muraca, 2010).

The energy management differs greatly between endosomatic and exosomatic processes. Organic bodies survive and develop by feeding on the only resource of low entropy 'infinitely' available on Earth: the solar energy that is captured by the planet's surface (*Land*) (Georgescu-Roegen, 1971) and transformed i.a. by photosynthesis. However, the flow of solar energy, which is infinite in its amount,[2] is not at our disposal with respect to the rate of its use. Endosomatic development depends on the flow rate of this basic source captured by Land like a fisher's net catches the fishes. The regeneration processes that keep that very 'net' at a constant level of functioning in order to support life require time. Through technological development, human beings managed to disentangle themselves from this temporal limitation by resorting to the so-called terrestrial stocks of low entropy (fossil resources resulting from a particular condition in the geological history of the planet, during which a big reservoir of low entropy accumulated into stocks). Other than solar-based flows, stocks of low entropy are not infinite in size, yet their flow rate can be somewhat accommodated according to society's needs – at least as long as they are easily accessible for exploitation.[3]

The problem with standard economic analysis is that it focuses on single production processes. In order to do that, it has to 'slice' the continuum into discrete parts identified by boundaries that neatly separate them from other processes (Georgescu-Roegen, 1984). What counts for economic analysis is what happens at the 'frontier' of a process – i.e. what enters or exit it (inputs and outputs). Both the transformation that occur between the boundaries and the processes occurring before and after it are neglected. While this seems to be a necessary methodological step to avoid infinite regress (otherwise nothing could be possibly excluded from the analysis of a particular economic process), it also abstracts from the real conditions that enable each process to keep working over time and fails to see its dependence on other processes.

Georgescu-Roegen proposes a different model based on a famous distinction between two different kinds of production factors, Funds and *Flows* (Georgescu-Roegen, 1971). To briefly remind us, Funds factors are the agents of production (Capital equipment, Ricardian Land, and Labor) that transform the flow of natural resources into a flow of economically valuable products. Funds have to be kept at their constant specific efficiency so that the economic process can be reproduced and are not consumed or used up in and by the process itself. Flow factors, instead, enter the economic process and are qualitatively changed or consumed through it. Flow factors are not only Inputs (resources) or Outputs (products and waste), but also Maintenance Flows, all those flows that regenerate Funds factors and maintain them in their condition of specific efficiency, including all assimilative or absorptive

[2] Technically speaking solar energy is not infinite. However, the whole perspective that Georgescu-Roegen takes here is that of a human time scale. For the same reason he writes that matter cannot be fully recycled: although this is physically possible, it does not seem to be a realistic perspective from the point of view of a human time scale (see also Kerschner, 2010).

[3] As we approach the maximum rate of extraction (peak) limits are imposed also on the access to fossil sources.

services that render economic processes possible in the first place. This refers both to natural and social processes: with a little leap of thought fitness centers or psychotropic drugs can be considered as maintenance flows that keep workers in good working conditions. The concept of Maintenance Flows is essential to understand the abstraction employed when the economic analysis focusses on the frontier of a process and fails to see its reliance on other processes, which – in turn – rely on other processes to keep going.

In this sense, many technological innovations are in the long run parasitic with respect to other processes and sources of energy. In 1984 Georgescu-Roegen addressed the illusion of technological development as the main solution to the scarcity of resources: "from all we know, to tap nature for her treasures (fossil fuels and even waterfalls) "tools" of greater and greater dimensions had to be used. More efficient machines need a greater amount of matter and energy to go through the whole economic process." (Georgescu-Roegen, 1984, 29). As long as we consider production processes only in terms of Inputs and Outputs – as neoclassical economics does – technologies represent a chance for increasing efficiency and reducing the consumption of resources. From this point of view it is important that a technology be *feasible*, which means that it can be technically and economically implemented. However, for Georgescu-Roegen feasibility means something more than just 'doable': "a process (or a recipe) is feasible if at the time of the discussion, we know all its specific flow and fund coordinates" (ibidem). Accordingly, while melting iron ore might be a feasible recipe, to control thermonuclear is not (at his time just as today!), precisely because we do not know all the coordinates in terms of flows and funds.

However important, feasibility is not the sole criterion that counts when assessing the biophysical and social impact of technologies. As soon as we consider the maintenance flows that some technologies require in order to regenerate the funds factors needed to produce them, we see that while many technologies may very well be feasible, they are certainly not *viable* (ibidem). In fact, "a technology is viable if and only if it can maintain the corresponding material structure and necessarily the human species." (ibidem, 29). The term *viable* is carefully chosen: it means literally capable of living without outside help, or – in other words – self-sustaining. A technology can only be self-sustaining if it generates – at least partly – its own conditions of reproduction by regenerating the funds (of course it cannot generate its own resources!) in a non-parasitic way. The regeneration of funds is time-related, as we have seen. By employing fossil resources that replace biological Maintenance Flows we can intensify regeneration processes temporarily. However, due to their parasitic character such interventions deplete in the long run the very Funds they sought to regenerate.

Rephrasing and extending Georgescu-Roegen's definition of viability to include sinks as well, Gowdy and O'Hara write that a technology is viable

„if and only if it can maintain the corresponding material structure which supports its resource and sink functions, and consequently supports human activity indefinitely under current environmental conditions. A technology that draws down irreplaceable stocks, or generates irreducible pollution, or violates the ability of funds to provide assimilative and restorative services, is not viable" (Gowdy and O'Hara, 1997, 242).

What is at stake here is not a refusal of technology or progress whatsoever. As we have seen, for Georgescu-Roegen technological development is the main characteristic of human cultural evolution. The question is rather what kind of technology makes sense in the long run and can be considered viable or sustainable (because, literally, self-sustaining): Viable technologies are consistent with the reproduction and regeneration times of the Fund factors and are minimally 'parasitic' (i.e. they do not rely on additional intensive sources, stocks or non-renewable resources imported from other places, taken away from future generations, or with heavily environmental impacts). While feasible technologies require the technical possibility of implementation and some predictability of outcomes, viable technologies are self-sustaining and life-sustaining, because they are based to a large extent on the only infinite source of energy on earth: solar flow and living funds (used according to their regeneration time and capacity). Finally, by designing viable technologies we should be aware of the irreversibility of transformative processes and include the perspective of future consequences.

The shift from renewable to non-renewable, fossil sources has enabled a remarkable acceleration and intensification in the production of new instruments. Moreover, terrestrial stocks have been successfully utilized for increasing and accelerating the productivity of renewable processes (see for example the use of fossil-based fertilizers). In an analogous way we could consider Climate Engineering as an attempt to accelerate/intensify the regeneration of the atmosphere as a sink. This path, however, leads to what Georgescu-Roegen calls an infinite regress, in which the Maintenance Flows for a particular economic process are produced by another economic process and so on. Ultimately, the continuous intensification of productivity is rooted in the accelerated depletion of terrestrial resources. In the end, this acceleration spiral leads back to the only unlimited source of low entropy, which is solar radiation as it is captured by Land and transformed by living organisms. But this resource is limited with respect to its flow rate. By using and abusing terrestrial stocks today in order to intensify the productivity of funds, we compromise the options of other people elsewhere and of future generations to do so (Muraca, 2010). Georgescu-Roegen knew very well that with the exosomatic development there is no 'natural' allocation of tools and instruments (Georgescu-Roegen, 1977). The distribution of access, availability, control, and impacts requires what he called a dialectical perspective (Georgescu-Roegen, 1971, 14ff) that goes way beyond the analytical approach of economics and necessarily implies ethical and political considerations. In the degrowth movement the biophysical analysis is closely combined with a socio-cultural perspective that re-actualizes the critique of technology articulated by Ivan Illich, André Gorz, Jacques Ellul, and Herbert Marcuse in the 1970s and adapts it to current challenges. This brings us to the second criterion for a degrowth-compatible technology: conviviality.

3.3. Convivial technologies: ecodemocracy against technofascism

According to Illich, while industrialization enabled the satisfaction of human needs and fostered to a certain extent emancipation, due to its capitalistic organization it also relied on the continuous creation of new needs and dependencies, thus increasing alienation (Illich, 1973). Accordingly, the Western logic of development reproduces itself by continuously recreating the basis for its self-legitimation until it reaches the status of a "radical monopoly" (Illich, 1973, 65f.) which leads to planned obsolescence, manipulates desires, and generates a feeling of lack. As a result, medicine makes us sick, school makes us ignorant, cars, which should make us faster, jam up the roads.

Scientific discoveries and technological development can improve the conditions of life by introducing new tools that are accessible to all, thus enlarging human creativity and self-determination. However, they are also exposed to an immanent logic of self-perpetuation, in which the increasing specialization and professionalization of experts require a constant extension of technical solutions to problems that in the first place are the consequence of former technical development. As Illich writes, "the

progress demonstrated in a previous achievement is used as a rationale for the exploitation of society as a whole in the service of a value which is determined and constantly revised by an element of society, by one of its self-certifying professional élites" (Illich, 1973, 20). The elitist power of experts roots in the collectively shared illusion that other forms of knowledge are of less value than scientific knowledge. Whereas a certain stage of scientific development remains accessible to a large majority of people and aims at generalization (Illich refers to the Chinese "barefoot doctors" who had a basic training in health care and significantly contributed to improve the health condition of people especially in the rural areas, albeit lacking any professional specialization), specialization leads to the creation of a corporate class of depositaries of knowledge who have the authority to decide about the criteria for access and implementation. The educational system turns thus into a technology itself that guards the gates.

In advanced industrialized society, technology can no longer be considered as a set of tools to be employed as instruments according to an aim-setting external to it. Tools are not only independent from ends, but shape and determine the ends – and for sure also the subjects employing them. Using and interacting with tools modifies us and the way we think, behave, and act (Ellul, 1989). From an anthropological point of view, technology is not a set of tools, but a form of relation to the world and to others, it embodies and shapes social relationships. Tools are carriers of meaning, reflect power relations, enframe the sphere of actions and collective practices. As Illich writes, "an individual relates himself in action to his society through the use of tools that he actively masters, or by which he is passively acted upon. To the degree that he masters his tools, he can invest the world with his meaning; to the degree that he is mastered by his tools, the shape of the tool determines his own self-image." (Illich, 1973, 34). The kind of tools a society chooses to employ and develop determines its political, institutional, and ethical fabric. This is why for Illich the decision about the role, limits, and meaning of technological development has to be embedded in participatory processes, to which all citizens have access and an active and substantial voice in the matter. In contemporary industrial societies, humans are driven into a drug-addiction-like state, in which they tend to lose their autonomy (i.e. the capacity to creatively deal with problems and find solutions adequate to the context) and risk being delivered to the systemic and technical forces of the development and growth machine. Like prisoners in rich countries, they have access to all sorts of things and services, but their freedom is limited to the consumers' role of deciding among different brands. Neither can they decide about how things are made nor about what to do with them. Technique as a system – i.e. a pervasive logic oriented towards increasing productivity, efficiency, and experts' control – represents, as Ellul says, for "contemporary human beings the world of necessity into which they find themselves inserted", the fatality of technique has replaced the fatality of nature in modern society (Ellul, 1989, 33).

The illusion of developing machines that work for and instead of humans, thus replacing slaves, has rendered humans slaves of the machines themselves and their logic of efficiency and uniformation. For Illich, instead, we need tools and machines to work with that enhance human creativity and enlarge the space of freedom, autonomy, and self-determination, instead of restricting it by imposing their own logic. In other words, we need 'convivial tools' that serve politically interrelated individuals rather than managers. Conviviality means for Illich "individual freedom realized in personal interdependence" (Illich, 1973, 24) and focusses on the quality of human relations, substantial freedom in terms of collective self-determination, and ongoing deliberation about the ends and forms of the commonwealth. Whether tools are convivial or oppressive does not depend much on their level of technology, but on how far they infringe the freedom and autonomy of the collective relating to them.

From an ethical point of view, technological development tend to enforce what Illich, by drawing on Marcuse, calls an institutionalization or materialization of values. Accordingly, values are translated into technical tasks and thus redefined as elements in technological processes (see Marcuse, 1964). As a consequence, the logic of technology determines the why and how of a new tool and not only the mode of its utilization. Objectives – a term borrowed from managerial language – replace ends. Against those who say that it is human beings who are responsible for making a good use of tools and impose ends on means, Ellul provocatively points out that this claim never specifies which human beings are intended: any passer-by, politicians, experts, intellectuals, or humanity as a whole? (Ellul, 1989). He rightly stresses that any ethical consideration about the limits, meaning, and role of technology cannot be disjoined from the political dimensions of power, access, autonomy, and agency. Any analytic distinction between means and ends, technology and its use, tools and intentions, that neglects the actual societal conditions under which both poles are intermingled and determine each other misses the target and can easily be used as a justification of the status quo.

Non-convivial tools exercise a 'radical monopoly', i.e. exclusive control "over the satisfaction of a pressing need" (Illich, 1973, 66) that excludes alternative practices, thus imposing one specific mode of relation (to the world and to others) and one specific path of problem solving. Where tools are only accessible to an elitist team of experts any public access or collective determination about their meaning, scope, and ends is reduced to an unequal and unbalanced exchange.

Faced with the urgency to address climate change, we might find ourselves caught again in the dilemma that Gorz depicted decades ago, i.e. the crucial alternative between conviviality and technofascism: either people agree on imposing limits to industrial production and technology through a process characterized by community-based conviviality and autonomy, or the decision will be taken by a central power of coordination and regulation, which will employ even more complex and less transparent technologies to cut people's autonomy (Gorz, 1980). The bureaucratic understanding of technology promises to solve environmental problems and to improve quality of life, while at the same time creating an élite of technocrats with power of control and leaving the large mass of people depending on them and their technological expertise.

Technology leads to uniformation and is even praised as a contribution to solve and avoid conflicts and foster agreement. This is precisely why leaving problem solving to the logic of technology embodies an even greater danger to democratic decision making: "A human society can only exist if it is based on the successive negotiations of contradictory positions" (Ellul, 1989, 34). This is only possible if the sphere of action encompasses a space for alternatives, as well as room for reconsiderations and reversal instead of being occupied by indisputable experts.

Summing up, Illich mentions three general principles of 'moral, political, and juridical procedure' for convivial technology: "recognition of the legitimacy of personal conflict, the dialectic authority of history over present procedures, and the recourse to laymen or peers for binding policy decisions" (Illich, 1973, 62). To reframe this in terms of the path for transformation envisioned by the degrowth movement: against radical monopoly we need a plurality of decentralized tools subordinated to collective decision making about ends and social relations; against techno-optimism we need to consider the complexity of (unintended) consequences in the future, the irreversibility of change, and the infringement of autonomy for future collectives; against

technocratic decision making we have to strengthen factual democracy by including non-scientific knowledge (such as indigenous knowledge, common experience and people's science) and other forms of knowing and pondering (ethical and social perspectives). As Illich warned "we need procedures that ensure that controls over the tools of society are established and governed by political processes rather than by decisions by experts" (Illich, 1973, 25). Finally, while standard technology is at the same time a main driver of economic growth (Boutellier and Heinzen, 2014) and in terms of large-scale investment in innovation it requires economic growth to be implemented and sustained, convivial technology would be largely independent of economic growth and its logic.

The actual access to deliberation requires both, distributive and participatory justice. To put it with the US-feminist Nancy Fraser, two basic conditions for effective participation (what she calls participatory parity) have to be secured: "First, the distribution of material resources must be such as to ensure participants' independence and 'voice'"; second, "it requires that institutionalized patterns of cultural value express equal respect for all participants and ensure equal opportunity for achieving social esteem" (Fraser, 2007, 27). Therefore, exploitation, gross disparities in wealth and in leisure time as well as value patterns that "deny some people the status of full partners" (ibidem) should be avoided, because they hinder the ability of all participants to interact as peers.

Against technocracy or technofascism, as Illich writes, "advanced or 'high' technology could become identified with labor-sparing, work-intensive decentralized productivity. Natural and social science can be used for the creation of tools, utilities, and rules available to everyone, permitting individuals and transient associations to constantly recreate their mutual relationships and their environment with unenvisaged freedom and self-expression" (Illich, 1973, 47). Convivial technologies are decentralized, reversible, and democratically controllable; they enhance autonomy and serve the good life of the community and are subordinated to the values and ends commonly negotiated. Almost 50 years after Illich, convivial technologies – from the new commons movement to open source technologies and modular machines for small-scale agriculture or transport – are even more realistic paths today, as the degrowth movement has highlighted. Projects like the P2P Foundation are working for "open, participatory processes of production and governance for the creation of common goods, whose universal access is guaranteed by licenses such as Creative Commons or the GPL (General Public License)."[4]

When addressing CE from the point of view of a conviviality perspective, we would have to ask how far large-scale intervention on the global climate via highly specialized technological expertise might reduce the space for democratic decision making and participatory processes that include non-experts. Moreover, we would have to move beyond the veil of CE technologies in terms of mere technical fixes to otherwise non-solvable problems and address what values they tacitly institutionalize or materialize and how they contribute to frame the terms of reference of the political discourse, as we will briefly show when addressing the Trade Off Argument later in the paper.

4. Degrowth-arguments and CE technologies

On the ground of the degrowth perspective outlined in the former paragraphs, two formalized arguments can be established and applied to Climate Engineering Technologies. There are good reasons why any technology T should be viable as well as convivial. That means that existing technologies should be modified, and newly developed technologies should be designed as to satisfy those criteria. This is the guideline when developing and deploying any CE technology T.

The Viability-Argument

1. A technology is compatible with a degrowth perspective if it is viable with respect to its maintenance flows.
2. A technology is viable if it (i) maintains its material structure which support its resource and sink functions, (ii) supports human activity indefinitely, (iii) works under/sustain current environmental conditions, and (iv) is not in turn parasitic on other economic processes that deplete funds
3. CE technology T suffices (i)-(iv).
4. Thus, from 1,3,4: CE technology is compatible with a degrowth perspective.

The Conviviality-Argument

1. A technology is compatible with the degrowth perspective if it is convivial.
2. A technology is convivial if it is (i) decentralized, (ii) democratically controllable, (iii) reversible, (iv) subordinated to the values and ends commonly negotiated and (v) accessible in terms of knowledge and affordability
3. CE technology T suffices (i)-(v).
4. Thus, from 1,2,3: CE technology is compatible with a degrowth perspective.

The two arguments work in an analogous way. Each argument states criteria that any technology must fulfill in order to be compatible with a degrowth perspective. These criteria are normative at least in the form of a strong regulative ideal. This means that technologies compatible with a degrowth perspective should at least clearly aim at satisfying both criteria and embody an evident tendency towards them, even if a full accomplishment of viability and conviviality cannot be achieved. While the first steps of the argument are normative, the penultimate step contains the rather empirical claim *that* a certain CE technology T fulfills those criteria. This premise might be true or false according to our state of knowledge. Each condition (i) – (iii) is by itself necessary, together they are sufficient for a technology to be viable or convivial. That means, as soon as CE technology T fails to meet only one of the criteria, it is no longer viable or convivial. This chapter is dedicated to the discussion of the empirical claim with regard to three specific CE technologies: Sulfate Aerosol Injection (SAI), Afforestation (AFF) and Bio-energy with Carbon Capture and Storage (BECCS).

4.1. Sulfate Aerosol Injection

The most controversial technology discussed so far is Sulfate Aerosol Injection. When considering the material flow of this technology, it seems worthwhile to ask where the sulfate comes from.

The sulfate that would be sprayed into the atmosphere (SO_2) occurs as a result of combusting sulfur. Sulfur can be found naturally or produced chemically. The natural resources are finite and hard to acquire. Made industrially, it is found as a by-product of the oil-refining process, but can be also made from petroleum and other natural gases.

Exploiting natural stocks for the production is hardly sustainable, as sulfur is a non-renewable element. Using the industrial product would rely heavily on the oil industry, which seems in direct contradiction to the envisaged transformation of society towards a post-carbon and post-growth future.

[4] https://blog.p2pfoundation.net/portfolio/our-story.

The proposed schemes as how to inject the gas in the atmosphere include the use of military or civil air force as well as balloons. Airplanes obviously need to be fueled, which would sustain an economic branch that contributes to the problem in the first place. One might argue that the implementation of SAI would only be for a short period of time, after which the use of planes and fossil fuels will eventually stop. How far this objection overrides the general concerns would have to be explored in more detail. Balloons don't face these problems. However, it is technically challenging to construct a balloon that carries the load to the needed height.

SAI, after all, is a form of designed pollution. The atmosphere is able to take a great amount of sulfate aerosol particles and slowly wash them out again. Possible consequences of this process might be the depletion of the ozone layer and the enhancement of acid rain (Heckendorn et al., 2009). How dangerous they might turn out to be depends on the amount and time-frame of the deployment. It is noteworthy, however, that it seems difficult to ethically justify the attempt to solve one environmental problem (climate change) by intensifying another one (acid precipitation) (e.g Robock, 2008). Whether and how those problems can be weighted against each other is debatable at the very least.

Altogether it seems plausible to assume that SAI will not be sustainable with respect to its material flows, given how strongly the technology is interlinked with fossil-fuel-based branches of the industry sector. A technology based on fossil flows must be discarded. However, if SAI were employed just as a means to bridge the time between now and a successful transformation of society towards degrowth and were stopped immediately after reaching this goal, it might in the end prove helpful.[5]

With regard to the management of deployment, SAI may be operated in decentralized way. The mechanism behind SAI is rather straight-forward, and the according expertise may be acquired within a few years (Barrett, 2008). The delivery-systems (plane or balloon, see Rickels et al., 2011) are also common technology, and overall, the technology is amazingly cheap. In case of catastrophic climate change, when urgent and prompt action is needed, even a single state could deploy SAI. But it is precisely this feature that makes SAI dangerous: How can the deployment be controlled, given that it is so cheap and easy? The question does not only address the factual deployment, but also and most importantly the extent to which SAI would reduce the temperature. The climate that benefits one country may harm another. Any discussion about the extent of any CE measure revolves around the decision about a "global thermostat" (Robock, 2008). Questions about asymmetries of power in decision making arise.

In terms of the effects, SAI surely is not decentralized, in fact, that's the whole point about any CE strategy: to influence the climate system as a whole. Even if the degree of deployment could be reached democratically within one country or community, this would not suffice to justify it, since it affects virtually the whole world. Consensus about deployment would have to be reached globally and include the voice of the social groups most affected by side-effects of SAI (Whyte, 2012). Under this perspective one would have to ask whether a technology, whose effects are global and largely unpredictable (and cannot be decentralized), is at all compatible with the critique articulated from a degrowth perspective.

The question remains whether a global democratic decision on SAI could ever be reached. There are several indicators that speak against this: Firstly, there is no international institution that is fit to regulate a global technology. There are efforts and already existing structures, like the International Convention On Biological Diversity (CBD) that could be used to regulate SAI. But the acceptance of this convention is purely voluntary (a comprehensive overview gives Reynolds, 2015). Some authors envisage a treaty on CE that is similar to the one concerning human genetics or nuclear weapon (Reynolds, 2014). There are several research projects on the legal questions and on the elaboration of a framework.[6] Still, it is highly controversial how to establish and enforce legal guidelines for CE that are globally accepted – especially in the face of the perpetuated incompetence of global statesmen and -women to even agree on climate targets. But even assuming that the world community mutually agreed on deploying SAI: If it is possible to agree on the deployment of SAI, it would also be possible to agree on mitigation. Thereby the prime reason for SAI – political inertia – would fade away. Stephen Gardiner, (2013) suggested as much, when he highlighted the possibility that the pursuit of climate portfolios including sincere mitigation might render CE strategies superfluous.[7] A paradoxic situation might arise, because as soon as we managed to democratically agree on SAI, we would no longer have to use it.

Lastly, the side-effects of SAI might be very severe und unequally distributed around the globe, and some of them might also be irreversible, The discussion is characterized by strong uncertainty. Questions that need answering include: What regional effects (positive and negative) might occur due to the deployment of SAI? How can climate impacts be attributed to SAI deployment? What compensation scheme would be fair for victims of SAI deployment? In some cases, people who are not included in common consent processes might suffer the most. For example, indigenous peoples today have no or very little say in international climate politics, but it is them who are most affected by it, for their entire way of life depends on an intact ecosystem (Whyte, 2012).

4.2. Afforestation

Afforestation ranges on quite the opposite side of the CE spectrum and might be quite suitable as a contrasting example. In this context, is not always clear what kind of technology still counts as mitigation and which one already should count as CDR. With respect to forestation, one can distinguish between Conservation, Reforestation and Afforestation. Where conservation and reforestation aim at saving or restocking already existing forest sites, afforestation means to plant fast-growing trees on fallow land, usually in the desert. Since this endeavor differs from conventional forest management in governmental, infrastructural and technical terms, afforestation can be seen as a CE technology.

At first sight, afforestation strategies seem little worrying. Planting trees is the symbol of sustainable and conscious stewardship of nature. Yet, greening the desert with an artificial forest or planting trees where crop should stand is a different matter. Hence,

[5] However that this kind of deployment is unlikely. The trade-off-argument shows the danger of lessening mitigation efforts under the deployment of CE. There is a likely danger of a prolonged deployment, once SAI is installed. It is questionable how to secure the termination of SAI deployment at the end of the planned time frame.

[6] The Priority Program "Climate Engineering – Risks, Challenges, Opportunities?" of the Deutsche Forschungsgesellschaft DFG consists in many different research projects. One of them is called "Climate Engineering Impacts: Between Reliability and Liability" (CEIBRAL). It focuses on the question of international liability regimes to control the potential deployment of CE. (DFG n.d., http://www.spp-climate-engineering.de/ceibral-kopie-319.html, access 07.04.2017).

[7] "Moreover, if a robust portfolio were really being enacted, the need for geoengineering research might be at least less pressing, and perhaps nonexistent." (Gardiner, 2013: 36).

afforestation strategies are as controversial as any CE technology.

As far as artificial plantations in arid areas are concerned, there is quite a logistic challenge. A specific proposal from Becker and his colleagues (Becker et al., 2013) suggests to plant heat resistant trees in the Arabian Desert. In costal areas seawater could be desalinated and be used for watering. Such "carbon farming" is, according to the authors, efficient (uptake 17–25t of carbon dioxide per hectare per year), and compatible with other forms of Carbon Removal, e.g. Carbon Capture and Storage (CCS) (Becker et al., 2013).

Still, with respect to the upfront technical investment, this form of Afforestation is quite elaborate. Roads must be paved, water must be desalinated, workers must plant the trees and control the plantation steadily. Without constant human input, the trees will dry up. From the point of view of viability, this seems quite parasitic on other processes.

Moreover, there is no ecological benefit from these plantations, since they are monocultures. On the contrary, they invade already existing and steady ecosystems in the desert, on which animals and some human communities rely. Thus, those plantations are neither sustainable nor self-reliant.

Another proposal is to use former agricultural land for afforestation. Here again, the line between re- and afforestation is quite thin, since much land used for agriculture was former forest, especially in the tropics. Here, afforestation schemes could go hand in hand with nature conservation efforts. However, these schemes may have influence on the food prices. Since afforestation and food production compete for land, any diminishing of farm-land may lead to higher crop prices. How high the rise may be depends on the amount of land converted into forest. In order to show effect, afforestation must be rather grand in scale. If, for example, 50% of the world's cropland was replanted, the carbon uptake would be about 50 ppm more as compared to a business-as-usual scenario (Arora and Montenegro, 2011). Even if only conservation schemes were to be implemented, non-forest carbon leakage could occur. Non-forest carbon leakage describes the process of turning non-forest land, that is not subject to conservation schemes, but contributes highly to carbon sequestration (e.g swamps or tundra), into agricultural land. In order to avoid this leakage and also stabilizing food prices, agricultural productivity would have to increase (Popp et al., 2014). This is a clear example of an infinite regress in terms of Georgescu-Roegen's analysis: to increase productivity fertilizers would have to be produced and the regeneration of the soil triggered by additional flow inputs.

Popp et al. (2014) and Arora and Montenegro (2011) calculate their scenario in light of a business-as-usual baseline scenario that adopts no other mitigation strategies. The effectiveness of afforestation schemes in tropical areas might increase, if at the same time global food waste is diminished, food choices change and food security is provided on a regional, decentralized level. On the same regional level, afforestation schemes can be planned and organized, which do not conflict with agricultural decisions and are significantly less parasitic on other resources and people. Enhancing models of afforestation that meet the needs and cultural traditions of people used to live off the forest could combine biophysical and social benefits and increase forms of autonomy in Illich' sense (food sovereignty and self-determination). It is questionable whether the size would suffice for a large scale CE technology.

As mentioned above, to avoid carbon leakage, preferably all forest-sites in question would have to be taken into account. The coordination and financial investments of afforestation schemes must be subordinate to a global forest policy.

If Afforestation is to be deployed in a viable and convivial fashion, its deployment alone will not stabilize the CO_2 concentration in the atmosphere. Afforestation can only be an additional measure in mitigation policy to tackle global climate change.

4.3. Bio-energy with Carbon capture and storage

Lately, hopes have been put on Bio-energy with Carbon Capture and Storage (BECCS). Biomass sequesters CO_2 from the atmosphere while it is growing. It then can either be burned for energy use or for producing bio-ethanol for transport. In each case, BECCS proposes to capture and store the CO_2 released during the burning process. That way, BECCS may account for net negative emission. The potential of BECCS is restrained by many factors, such as land availability, food demand, and future climatic and social developments. Currently, this potential is massively limited by the availability of arable land. The conversion of agricultural land into biomass plantations is determined by food demands, dietary choices and might include heavy fertilization (Schäfer et al., 2015; McNutt et al., 2015). Again, Georgescu-Roegen has a strong point about the infinite regress that would ultimately end up on Land as a Fund.

If BECCS were to be used in a way consistent with RCP2.6, i.e. in order to reach the 2-degree-target, the estimated land-use of food-production and biomass-production would go up to 2.1 billion hectares in 2100. To put this number into perspective, today's cropland are 1.6 billion hectare (McNutt et al., 2015). The conversion of land into biomass plantations must suffice certain ethical criteria. One set of ethical principles is proposed by the Nuffield principles on Biofuel (Nuffiled council on bioethics 2011: 84):

i. Biofuel development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements).
ii. Biofuels should be environmentally sustainable.
iii. Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change.
iv. Biofuels should develop in accordance with trade principles that are fair and recognize the rights of people to just reward (including labor rights and intellectual property rights).
v. Costs and benefits of biofuels should be distributed in an equitable way.

The first two principles refer to land-use problems. This is especially important if biomass is produced in the Global South, where arable land is scarce and the available cropland is essential for self-sufficient, small-scale agriculture. Moreover, if animal rights and species conservation are considered, the conversion of wildlife habitat would not be an option either.

The third principle is about effectiveness. As it has been noted recently, that BECCS might create a feedback on the carbon cycle. When carbon dioxide is removed from the atmosphere, the ocean might release CO_2 in order to balance the artificial carbon loss (Chen and Tavoni, 2013). Also, soil carbon emissions during and after the plantation of biomass may reduce the net negative emissions of BECCS (Pourhashem et al., 2016).

The fifth principle refers to the issue of environmental and distributional justice and includes the conviviality criterion. While the benefits of BECCS are meant to be global, the side-effects are local. They range from land loss to decreased standard of living by the infliction of newly established infrastructure, and ultimately to the potential leakage of geological storage. If carbon dioxide leaks from the underground caverns, the poisoning of habitats, such as rivers and seas, is possible, as well as the suffocation of animals and humans.

Land-use conflicts may be prevented partially, if food-production where to use less land. This might either happen via

increased productivity or via a change in food choices. Increasing the productivity of food-production might be possible in some regions of the world, but mostly via parasitic measures (such as the employment of chemical fertilizers). Conventional agricultural practices do not only account for loss in biodiversity and soil overexploitation, but also for unjust food prices and ultimately to the abuse of farm-factory animals.

Highly specialized and fertilized monocultures of biomass are not compatible with the two requirements of viability and conviviality. Moreover, the agricultural infrastructure needs to be augmented and needs constant care. The current stream of maintenance might outweigh the benefit of BECCS, regarding both the increased cost and the energy needs.

On the other hand, a change in dietary choices of western cultures may well contribute twofold to the solution of climate change. If Western diets were to be mostly vegan, intensive meat-production – a great CO_2 emitter – could decline and thereby open up arable land for biomass production.

Regarding energy security, BECCS might play a role. Since biomass can regrow, BECCS can count as a renewable energy source. However, BECCS alone might not secure energy demands and would increase the competition on land as states above. Thus, it seems wiser to focus on different renewable energy sources like solar or wind energy. BECCS can only play an auxiliary role to energy security and to the mitigation of climate change.

Finally, BECCS power plants require a huge amount of upfront investments. While the use of biomass might be controlled locally (from growing to generating energy), the infrastructure for transport and storage of CO_2 may not. Also, the technology to capture CO_2 point source is fairly advanced and may not be available to non-professionals. Accordingly, BECCS plants may not be established in a decentralized and accessible way. BECCS is not a technology that can support energy independence for small villages or self-managed communities. It is a hegemonic technology, just like SAI. In comparison, other renewables such as solar or wind energy work locally, and could also be compatible regarding cost and CO_2 emissions.

While the management of BECCS may not be local, the side effects are. The gravest side effects might occur during transport and storage. Leak pipelines may cause highly concentrated carbon dioxide pollution. If storage sites are not safe, for example due to seismic activity, leakage may contribute to severe CO_2 pollution. A devastating, though natural example of a CO_2 pollution is the 1986 Lake Nyon disaster. Lake Nyon, located in the Northwest region of Cameroon, houses a magma chamber filled with carbon dioxide. In August 1986, the lake released a huge cloud of about 300.000 tons of CO_2, which caused at least 1700 people and 3500 animals to suffocate. The eruption was probably caused by underground seismic activity (e.g. Kling et al., 1987).

Catastrophes like this ought to be ruled out. Since this is near to impossible, because both seismic and volcanic activity is still not sufficiently predictable, storage of CO_2 can never be fully safe. This is true for both geological caverns as well as deep-sea storage. While the leakage in the former may affect land-animals and humans, the latter may affect sea-animals. Those side-effects would be most intense at the storage site and hence would occur locally.

Additionally, carbon storage might be a problem for future generations. Confronted with deep uncertainty, current decisions makers cannot oversee all possible incidents and side-effects related to carbon storage. In this sense, BECCS passes down the buck to future generations. It defuses the current problem of air pollution into a future problem of artificial carbon sinks. The obligation to reduce emissions cannot be met by carbon storage. Having said that, recent studies suggest that the probability of leakage is fairly low (Wennersten et al., 2015). If so, future decision makers could still decide upon carbon storage.

In summary, BECCS is prone to issues of both procedural and distributional justice. Benefits and side effects of BECCS should be distributed fairly, and the governance of BECCS needs to be democratic and transparent. In how far this is possible, is still an open question.

Research and development of BECCS means also research and development of fossil Carbon Capture and Storage (i.e. capturing carbon when burning fossil fuels). In fact, if storage sites and successfully working CCS plants are limited, fossil fuel based industries will have a strong interest to use this technology (McNutt et al., 2015). This might enhance the continued use of fossil fuels and sustain economic business as usual.

Lastly, it is important to note the status of BECCS at the moment. As introduced above, studies suggest that, in order to reach the climate goals of the Paris Agreement, negative emission technologies and foremost BECCS are essential (e.g. UNFCCC, 2016). It seems that speculating on BECCS will become a self-fulfilling prophecy: The stronger BECCS is anticipated, the lesser is the pressure to pledge for drastic and short-term emission cuts (Fuss et al., 2014). This observation is the real life example of what has been dubbed the trade-off-argument against Climate Engineering, which shall be discussed in the following chapter.

In conclusion, large-scale BECCS does not meet the criteria of being viable or convivial. It is a cost-intensive technology that requires a high level of professionalism and infringes the autonomy of local communities, which might be overruled in the decision process. Its side-effects may be serious while affecting local people and biological systems. It is overall not sustainable with regards to its material structure. If intensive deployment of BECCS is desired, unsustainable agricultural practices might be applied. Finally, BECCS might fall afoul of considerations regarding future ethics.

5. Reframing the trade-off argument from a degrowth perspective: a critique of business-as-usual development strategies

The model of intervention in CE technologies such as SAI might help to sustain the current model of economic development based on economic growth by reducing the harmful impacts of it on the global climate, at least so the promise attached to it. Regardless of a critical perspective on specific technologies and their impact, a more general critique against interventions that support business-as-usual models in order to maintain a 'sustainable growth path' for the future can be formulated from a degrowth perspective: limiting the impact of GHG emissions while continuing business-as-usual development based on economic growth will exacerbate global environmental conflicts, jeopardize quality of life, and enhance crises worldwide. This kind of critique can be framed from an applied ethics perspective by extending the well-studied moral-hazard or Trade-Off-Argument (TOA). The TOA can be used to substantiate the claim that some CE technologies might have a generally negative impact on society in terms of delaying or hampering more fundamental transition steps towards the radical social-ecological transformation envisioned i.e. by a degrowth perspective. If this is true, any CE technology must be rejected in principle as part of the problem and not of the solution (we refer here to the structural analysis of growth-societies – see Section 3.1).

The TOA states that the prospect (or research and deployment, respectively) of a CE technology will interfere with the moral obligation that current generations – even more in the Global

North – have to adopt serious mitigation strategies against climate change, making it unrealistic for the current generation[8] to comply with it (Baatz, 2016; Betz and Cacean, 2012; Hale, 2012; Lin, 2012; Morrow, 2014). CE measures may present the possibility to at least slow down dangerous climate change without costly mitigation strategies. The mere prospect of CE and *a fortiori* the deployment of CE thus takes away the incentive for drastic emission-cuts.

This is the basic form of the trade-off-argument (specified to the deployment of CE):

Trade-off Argument (TOA)

1. The current generation is required to adopt serious mitigation strategies (MO).
2. Deploying CE technology T will (is likely to) prevent the current generation from adapting serious mitigation strategies.
3. If agent A is required to do Y and doing X will (is likely to) prevent her from doing Y, then agent A must not do X.
4. Thus: The current generation must not deploy CE technology T.[9]

Premise (2) of TOA states that deploying CE will somehow hamper the required mitigation efforts. In conclusion, deployment of CE should not be undertaken. As illustrated above, the mere prospect of BECCS may already be responsible for insufficient mitigation pledges. On the other hand, knowledge about SAI does not necessarily lead to a decline in individual mitigation efforts (Merk et al., 2016). Trade-offs depend on the type of technology and its associated side-effects. But more importantly, it seems to depend on the level of agency and the existing constraints of a capitalistic economy. While individuals may be *willing* to change their lifestyle and reduce their carbon footprint, they might not actualize this intent, for the current economic structure limits their radius of operation. This holds even more for the industrial sector. Especially companies with the biggest impact on climate are completely dependent on the growth paradigm to generate and increase profit, while externalizing effects on society. Obviously from this perspective, minimizing mitigation costs in the short run is the most attractive option, which can be easily accomplished by externalizing environmental costs to other regions (and/or vulnerable social groups) or to the future (discounting). From this point of view, choosing not to adopt (costly) mitigation strategies if there are other (cheaper) alternatives in sight, is rational from a business-as-usual perspective rooted in ongoing economic growth. In other words, the current economic paradigm makes trade-off-choices rational and generally more attractive, even if individuals may chose differently.

The TOA can be used to introduce mitigation efforts to a broader understanding of social change. Mitigation without a clear step away from a fossil-fueled economy is not only shortsighted, but also hazardous. This consideration highlights the importance of a transformation that addresses social, ecological, and economic issues and considers the interlink among institutions, collective practices, and individual behavior. This essentially involves a transition towards a low- or even post-carbon society.

As it is presented here, the TOA presupposes an economic rationality that is coupled with the growth paradigm. Paradoxically, the deployment of CE technologies might not lead to such trade-offs if embedded in a degrowth-like society, in which ideally the drivers of expansion and accumulation would no longer hold. In a degrowth climate portfolio a moderate CE deployment might be imagined that would not infringe mitigation efforts. In conclusion, the TOA might no longer speak against CE deployment, if the growth paradigm is abandoned.

Nevertheless, as shown in the previous chapters, under a degrowth perspective neither SAI nor BECCS are candidates for viable and convivial technologies. Afforestation might to a certain extent help to enforce mitigation strategies, but surely cannot replace drastic emission cuts. Even disregarding TOAs, it is questionable whether CE technologies might help transitioning towards a society envisioned by degrowth. They might buy us time for the transition, but the side-effects of a short-term deployment would have to be carefully weighted against the benefits. The pressing questions are about governance and how to guarantee the termination of the deployment.

Having said that, it is likely that some form of CE will be deployed soon as we are running late for mitigation. At least BECCS is supposedly the best chance we have to possibly reach the 2-degree –target. If this is true, then all efforts should be put into measures of control for BECCS, by establishing regulations and ensuring the termination of any CE scheme. It is doubtful whether this could work under the dominant growth paradigm and the drive to increasing accumulation.

6. Conclusion

This paper articulates two criteria for a critical consideration of technologies from a degrowth perspective and applies them as formalized arguments to a detailed normative critique of Climate Engineering, with a particular focus on three CE approaches: Sulfate Aerosol Injection, Afforestation and BECCS. On the ground of the analysis it can be said that none of those technologies either fulfills the criteria of being convivial or viable or displays a clear regulative tendency towards them. Especially SAI must be rejected from a degrowth perspective both due to its parasitic nature and lack of transparency.

From an ethical perspective, the current generation will not be able to fulfill the moral obligation to limit climate change by deploying BECCS, SAI or by Afforestation. The ethical status of climate change as a human-made disaster calls for strong efforts to mitigate, and not for a diffusion of the problem onto the future.

Moreover, by analyzing the Trade-Off-Argument, it was shown that CE deployment might even hinder a transition towards a social ecological transformation as envisioned by the degrowth movement by creating trade-offs to mitigation under the current dominant paradigm of growth and capitalistic accumulation.

Only with considerate global and regional governance and corresponding mitigation schemes CE technologies might possibly help counteract climate change, while at the same time enabling a social-ecological transformation. This, however, depends on the scale and length of deployment, which in turn is dependent on policy decisions, economic interests, and the asymmetry of power relations. Moreover, large-scale technologies to control the climate infringe participation and limit the sphere of self-determination especially for those communities who are already the most vulnerable to and the least responsible for climate change itself.

In conclusion, we can say that what sounds at first as a feasible technological innovation bears a set of more or less unintended consequences and – in order to have a chance of being successful – it requires a number of institutional measures, policy interventions, and social adjustments that limit its very feasibility. Only by

[8] The question of agency is diffuse. If the obligation to mitigate is located at the individual level, it might be fair to assert a per capita carbon budget. Summed up, this could account for the carbon budget of a state. Accordingly, states with the biggest emissions per capita would have the strongest obligation to cut emissions. However, historical responsibilities and ability to pay also play an important role when it comes to identify who in the current generations has a stronger obligation to mitigate. When talking about obligation for current generations of the Global North, this is not only a geographical indication, but refers to those who benefit(ted) most from climate change across and within countries.

[9] Thanks to Gregor Betz for the helpful comments on this reconstruction.

neglecting the complex biophysical and socio-political setting, in which technological developments are embedded, they might appear as a simple solution path. The promise of securing business-as-usual modes of production and consumption by employing technological innovations cannot hold: even if they might be very well feasible, they are neither viable (since they are heavily parasitic on other biophysical processes) nor convivial (since they can be successful only on a large scale and with modes of reproduction that imply concentration of power and exclusion of otherized voices). In light of those challenges, it seems little promising to seriously consider any CE technology for a degrowth pathway.

There is a number of alternative bottom-up actions all over the world that already implement mitigation under the perspectives of viability and conviviality and address the causes of climate change. Given that industrial agriculture is one of the main drivers of climate change, models of sustainable small-scale farming and local food consumption, like those that La Via Campesina embodies, address for example the core of the problem by avoiding parasitic loops onto other processes and by strengthening autonomy and self-determination (La Via Campesina 2009). These include by all means social and technological innovations that do not manipulate the global climate and are decentralized, viable, and convivial.

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Annex

Table 1
Do the technologies fulfill the degrowth-based criteria of viability and conviviality? Dark grey indicates that the technology does not fulfill the corresponding degrowth requirement. Light grey indicates an uncertainty or the need for further specification under current societal conditions (this is discussed in the text). The asterisk means that the non-compliance with the requirement is due to the storage problematic with BECCS.

	SAI	AFF	BECCS
The Viability-Argument			
(i) maintains its material structure which support its resource and sink functions	No	Yes	No
(ii) supports human activity indefinitely	?	?	?
(iii) works under/sustains current environmental conditions	No	No	No
(iv) is not in turn parasitic on other economic processes that deplete funds	No	No	No
The Conviviality-Argument			
i) decentralized	No	No	No
(ii) democratically controllable	No	No	No
(iii) reversible	?	Yes	No*
(iv) subordinated to the values and ends commonly negotiated	?	?	?
(v) accessible in terms of knowledge and affordability	No	No	No

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